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TM 75-20 - Wind-Driven Power Supply for Advanced Beehive Fuze--by Henry C Lee Leland R Jones

Wind-Driven Power Supply for Advanced Beehive Fuze

November 1975

RESEARCH
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HARRY DIAMOND LABORATORIES
Adelphi, Maryland 20783

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

A wind-driven fluidic generator of the reed type has been developed at the Harry Diamond Laboratories (HDL) as a power source for the Advanced Beehive Fuze.

Results of laboratory studies and field tests conducted in 75-mm Howitzers indicate that the fluidic generator is capable of meeting the muzzle action requirements of the Beehive fuze. Air-

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gun test results indicate that the device is mechanically rugged to withstand the high setback force environment (25 k g) encountered by the Beehive rounds.

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FIGURES

TABLES

1. INTRODUCTION

This report describes the design, operation, and test results of a reed-type fluidic generator intended for use in the Advanced Beehive Fuze.

The Advanced Beehive Fuze (fig. 1) is an electromechanical fuze that uses the reed-type fluidic generator as a power supply and electronic circuitry for setting and functioning the fuze. The fuze electronics

Neg. No. 49-186-1108 1972

Figure 1. Section view of fluidic generator powered Advanced Beehive Fuze.

[1]*Campagnuolo, C. J., The Fluidic Generator, HDL-TR-1328 (September 1966).*

consists of an oscillator scaler, counter, firing, and interface circuits. The component that provides memory in the fuze is the counter, which makes use of the metal nitride oxide semiconductor (MNOS) technology. This type of memory retains the set time without electrical power. The fuze system also includes an external setter that sets the fuze in terms of time of flight. The fluidic generator[1] is required to (1) provide electrical power to initiate the fuze within 16.4 ft of the gun muzzle at velocities from 1400 to 3000 ft/s, and (2) provide a minimum of 22 V(dc) and 10 mA into the equivalent 2.2-kohm load during the entire flight range of 9840 ft.

The generator developed consists of a ringtone fluidic oscillator and a reed-type magnetic transducer (fig. 2). The design that evolved for the Beehive generator, its operating characteristics, and the results of experimental and field tests conducted are described in this report.

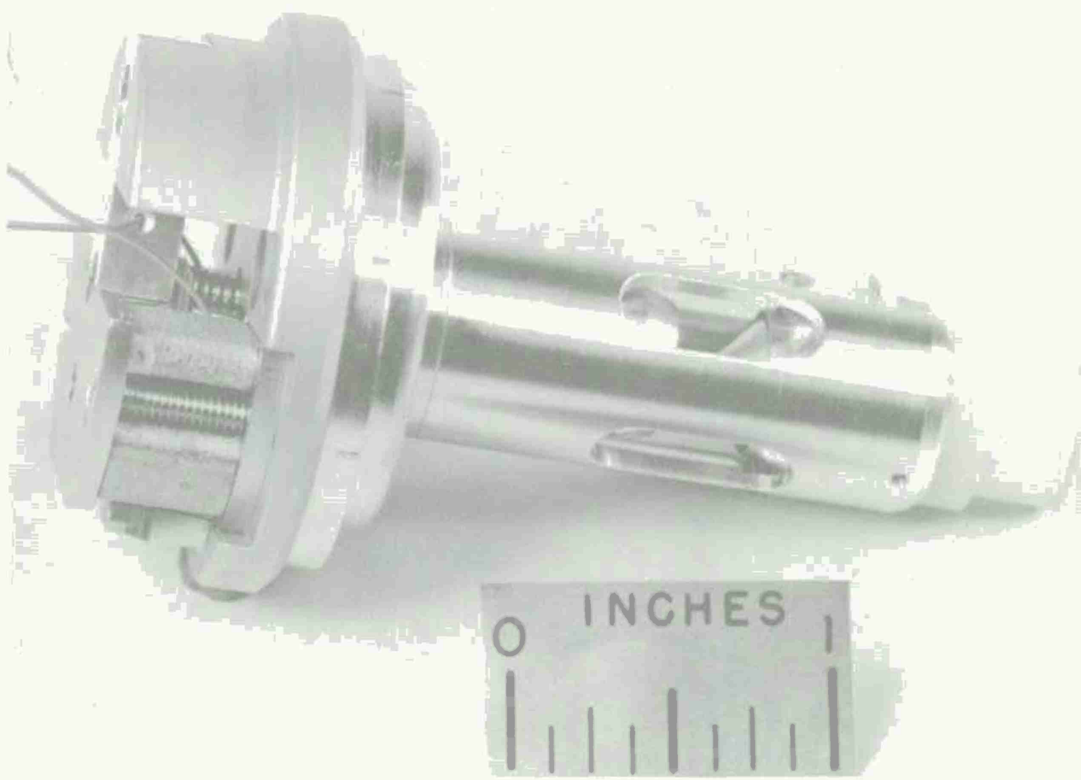

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Figure 2. Fluidic generator for Beehive fuze application.

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[1]*Campagnuolo, C. J., The Fluidic Generator, HDL-TR-1328 (September 1966).*

2. GENERATOR DESIGN

The generator considered for the Advanced Beehive application is a reed-type ringtone generator consisting of a ringtone fluidic oscillator (fig. 2) that triggers a diaphragm at resonance. The diaphragm drives a reed positioned between the poles of a permanent magnet. The magnetic field of the poles is switched alternately during each cycle of the oscillating reed, thus inducing an emf in a coil around it. Previous laboratory and field tests[2] have shown that the reed-type ringtone generator is capable of functioning over the velocity range required for the Advanced Beehive round. However, the electrical power requirements of the Beehive fuze electronics have necessitated a redesign of the electromagnetic transducer so that it will produce the required voltage and current. The mechanical components of the generator assembly were also redesigned to withstand the high-setback force (25 kg) experienced by the Beehive rounds.

2.1 Impedance-Coil Study

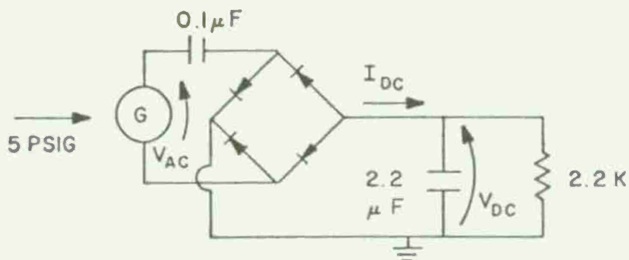
During muzzle action, when the Beehive fuze circuit firing capacitor is undergoing the initial charging cycle, the electrical impedance of the equivalent circuit changes from a minimum value of less than 500 ohms to its steady-state value of 2.2 kohms. The design procedure consists of matching the electrical impedance of the generator to that of the Beehive fuze circuit. This procedure was necessary to insure that the generator would provide the arming voltage (22 V) within the required 5-m arming distance, and maintain a steady 22-V minimum output and 10 mA for the duration of the projectile flight.

Laboratory tests were conducted to: (1) determine the matched coil impedance so that the generator could provide the required arming voltage and current, and (2) measure the arming time of the fuze. For the tests, the output of the ringtone generator, after rectification, was directed to an equivalent Beehive load circuit, which consisted of a 2.2-kohm resistor in parallel with a 2.2-μF capacitor. Of seven coils tested, the output impedance ranged from 80 ohms (No. 34 wire with 700 turns) to 5 kohms (No. 44 wire with 4000 turns). These impedance values were the corresponding ac resistance of the coil at which the generator output is maximum. The peak voltage (dc) across the 2.2-μF capacitor was recorded. The data obtained are shown in table I. Note that for inlet pressure of 5 psig (750 ft/s), the No. 36 wire (1500 turns) with an impedance of 500 ohms yields the highest voltage (44 V) when compared with the other coils. Figure 3 shows the voltage output of the

[2]*Campagnuolo, C. J., L. Richmond and P. Ingersoll, Hi-Performance Point Detonating Fuze in Mortar and Artillery Concept Formulation, HDL-TR-1577 (December 1971).*

TABLE I. MEASUREMENT DATA TAKEN ACROSS 2.2-μF CAPACITOR

Coil size	Coil turn	Imped-ance	Volt ac	Volt dc
34	700	80 Ω	36	16
33	500	80 Ω	26	12
36	1500	500 Ω	85	44
38	1500	500 Ω	75	35
40	2000	800 Ω	70	32
42	3000	2 kΩ	60	30
44	4000	5 kΩ	50	25



generator with the coil of No. 36 wire (1500 turns) over the velocity range from 500 to 1200 ft/s. Note that at 750 ft/s--the minimum flight velocity for any Beehive round--the generator produces 44 V and 48 V at 1200 ft/s.

Initial laboratory measurements also indicate that the coil with 1500 turns of No. 36 wire charged the 2.2-μF capacitor in less time (to 22 V) than did the other coils tested. The actual arming-time measurements were conducted in the wind tunnel at the Aberdeen Aeroballistic Laboratory.

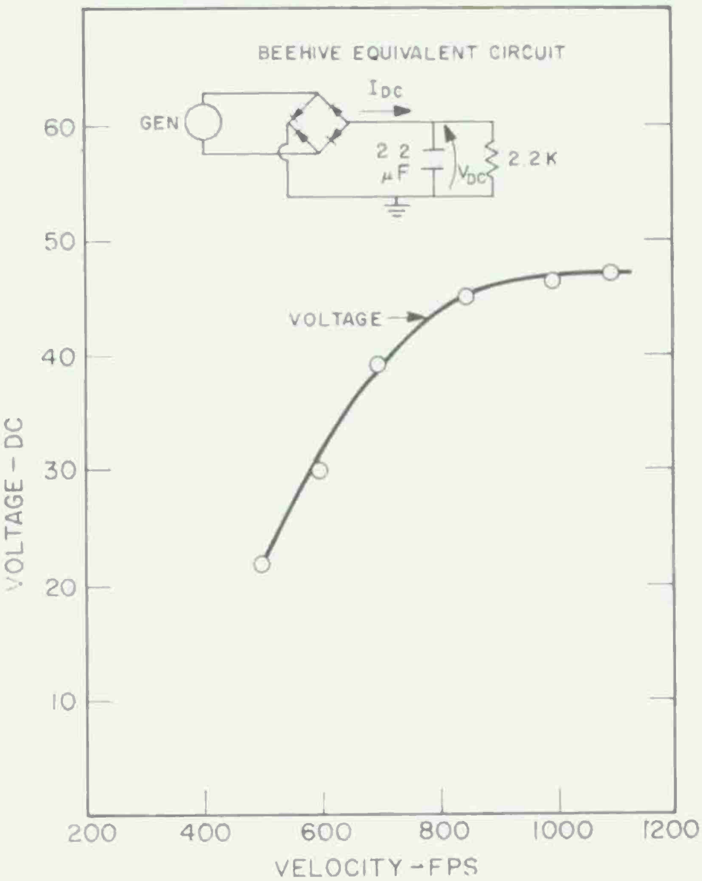


Figure 3. Beehive generator voltage and current output.

2.2 Arming-Time Measurements

The major usage of the Beehive fuze is the "muzzle action" in which the round is initiated within 16.4 ft of the gun at muzzle velocities ranging from 1400 to 3000 ft/s. A spin-activated S & A arms the fuze prior to muzzle exit, and the fluidic generator provides the electrical firing voltage as the round leaves the muzzle. Arming time is defined as the time required for the generator to charge a 2.2-μF capacitor of the Beehive fuze circuit to a required arming voltage of 22 V. As discussed earlier, this arming voltage must be obtained within 16.4 ft from the gun or within 11.7 ms (at 1400 ft/s muzzle velocity) and 5.5 ms (at 3000 ft/s muzzle velocity).

Arming-time measurements were first conducted in the BRL supersonic wind tunnel (fig. 4) at Mach numbers 1.5, 1.7 and 2.0. For the test, a reed-type generator was placed inside the fuze ogive. The output of the generator was rectified and then directed to a Beehive

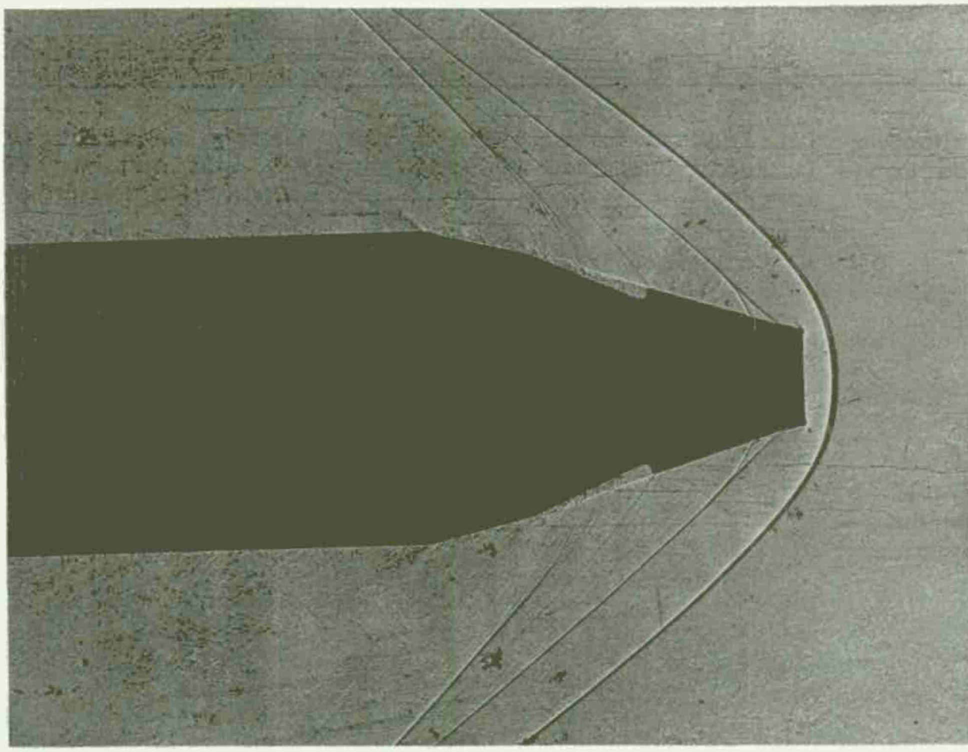


Figure 4. Shadowgraph of the Beehive fuze ogive taken in the supersonic wind tunnel.

equivalent fuze circuit which consists of a 2.2-μF capacitor in parallel with a 2.2-kohm resistor. The wind-tunnel measurement was conducted as follows: Prior to each Mach number setting, the inlet orifice of the generator was sealed with adhesive tape. When the flow condition corresponding to a preset Mach number was established, the sealing tape was removed quickly by pulling a lanyard through the side of the wind tunnel test section. Once the inlet orifice was uncovered, the generator was exposed to the wind-tunnel dynamic pressure and generation of electrical energy began instantaneously. The voltage from the generator triggered an oscilloscope that was set to record the charging voltage of the 2.2-μF capacitor. A schematic diagram of the test setup is shown in figure 5. Since the arming time is strictly a function of the output power and impedance of the generator, wind-tunnel arming time was measured in terms of given generator power output. Due to low static pressure, which resulted in lower inlet pressure as well as mass flow to the generator, the generator output power at Mach numbers 1.5 and 1.7 was below the required 0.3 W needed to charge the 2.2-μF capacitor to 22 V. Hence, no arming time was established. The only

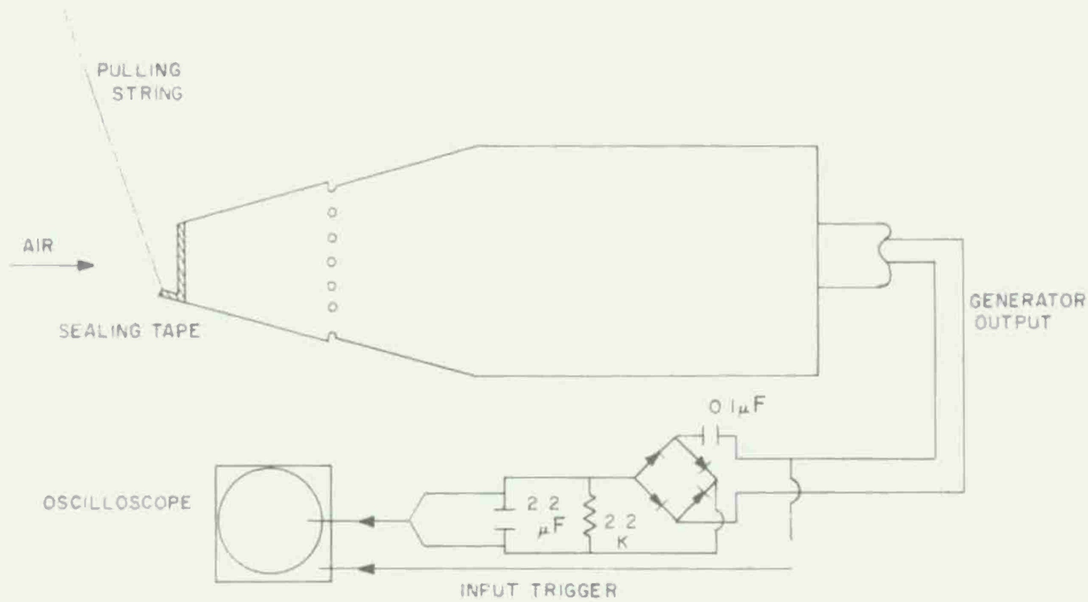


Figure 5. Schematic diagram of wind tunnel arming time-measurement setup.

measurement obtained was at Mach number 2.0. The arming time was measured to be 4.0 ms at a corresponding output power of 0.75 W. This measurement correlates to a muzzle velocity of about 1000 ft/s. To obtain arming time between 1400 and 3000 ft/s, a laboratory simulation of muzzle action was conducted.

In the laboratory, muzzle action was simulated by means of a stagnation chamber in which the input pressure to the generator can be regulated to any desired muzzle velocity. A solenoid valve was used to release the pressure to the generator. A Kistler pressure transducer positioned at the generator nozzle measured the incoming pressure. The pressure signal from the transducer and the charging voltage across the 2.2-μF capacitor were recorded on an oscilloscope which provided the arming-time measurements. The power output of the generator was also recorded on a power meter. Figure 6 shows the laboratory measurement arming time as a function of muzzle velocity and generator power output. At 1000 ft/s, the laboratory arming time is about 5 ms, which is in close agreement with the wind-tunnel measurement. At the maximum generator output power of 1.4 W, the corresponding arming is about 3.5 ms. Since the generator reaches its maximum power at 1400 ft/s (the minimum expected Beehive muzzle velocity), the predicted arming distance is between 4.6 ft (at 1400 ft/s) and 10 ft (at 3000 ft/s). At this velocity, the generator produces 10 mA and 22 V. This is the required arming current and voltage to the Beehive fuze circuit.

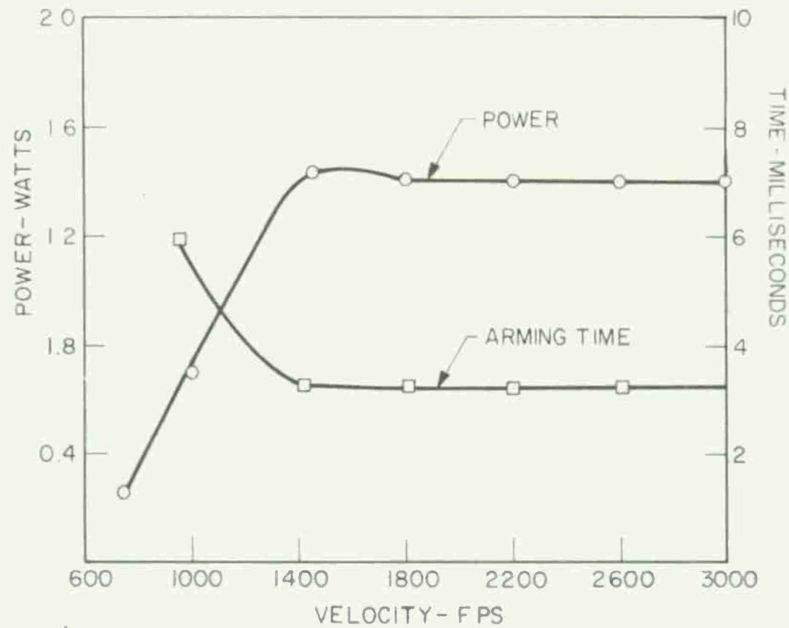


Figure 6. Beehive generator power output and corresponding arming time as a function of muzzle velocity.

2.3 Air-Gun Tests

A structural study of the reed-type generator was conducted. The HDL air gun was used as a test vehicle to generate 30-kg (peak g's) setback force. Power output of the generator was measured before and after each air-gun test to determine the effect of setback force on generator performance. Based on the results of a number of tests, the coupling of the reed to the diaphragm (fig. 7) was changed from a rigid lock-nut joint to a system whereby the reed is coupled to the diaphragm by means of a helical compression spring. A slot was cut in the reed that allows the diaphragm-rod-reed assembly to travel unobstructively during setback until the spring is compressed and the nylon washer bottoms. In this design, the spring absorbs most of the setback forces, thus preventing the diaphragm from being overstressed. In addition to the above design changes, the reed was changed from a single reed (0.018 in. thick) to a double reed (each 0.018 in. thick) to provide increased mechanical strength.

Five generators incorporating the new design changes were subjected to air-gun tests. The power output before and after the shock test for each generator is given in table II. The data in table II show there exists some power degradation due to setback force. However, the remaining power level was sufficient to power the Beehive electronics for muzzle action as shown by the field test.

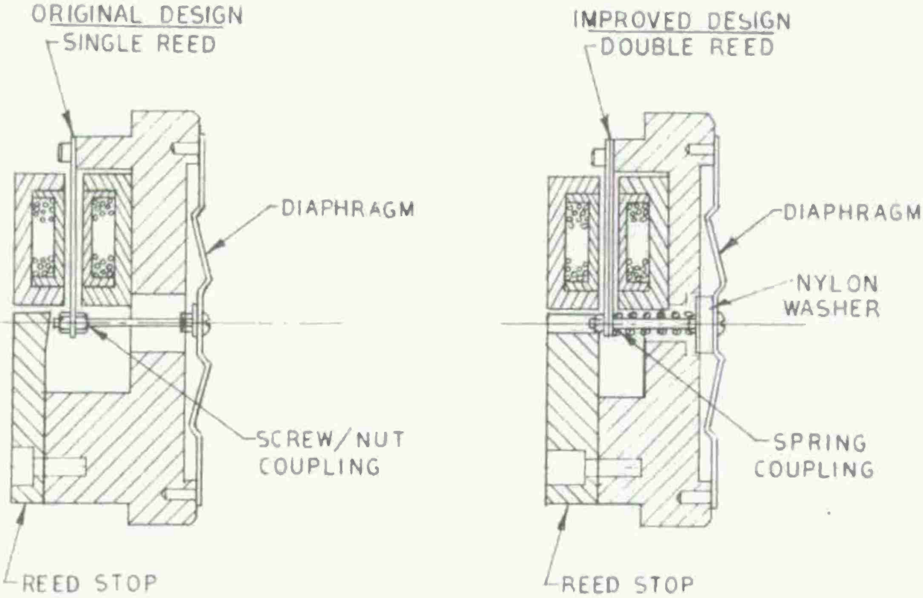


Figure 7. Schematic diagram of fluidic generator design modifications.

TABLE II. POWER OUTPUT OF DOUBLE REED-TYPE FLUIDIC GENERATOR BEFORE AND AFTER AIR GUN TEST[1]

	Power (MW)									
Test No.	1		2		3		4		5	
Test Cond.	Before	After	B[2]	A[3]	B	A	B	A	B	A
Pressure (PSIG)										
10	265	250	325	250	575	250	550	325	375	250
12	325	350	475	325	775	350	700	450	475	325
14	400	400	675	450	1000	425	825	575	600	400
16	600	480	850	575	1150	575	1000	675	750	475
18	800	550	1150	750	1400	725	1200	800	900	575
20	960	600	1300	950	1600	1000	1400	950	1000	700

[1]*Shock = 25,000-g Avg., 30,000-g Peak.*
[2]*B = Before.*
[3]*A = After.*

3. FIELD TESTS

Based on the results of the air-gun tests, several generators were redesigned and tested in the field for muzzle action function. The test was conducted at the HDL test range at Blossom Point, using the 75-mm Howitzer cannon at charge 4. The projectiles contained flash charges that ignited when muzzle action occurred.

3.1 Test Procedure

The tests were conducted with standard 75-mm projectiles, M48, filled with wax. A cavity was bored in the projectile to accommodate the flash charge and fuze intrusion. The gun was placed in line with a standard 8- by 4-ft plywood sheet, followed by a row of stakes placed 3 ft apart and labeled A through F (see fig. 8 and 9). One high-speed camera (4000 frames/s) was used to photograph the occurrence of muzzle action within 16.4 ft and a second high-speed camera was used to photograph the region between 16.4 and 32.8 ft. Timing marks of 1 ms were provided on the film.

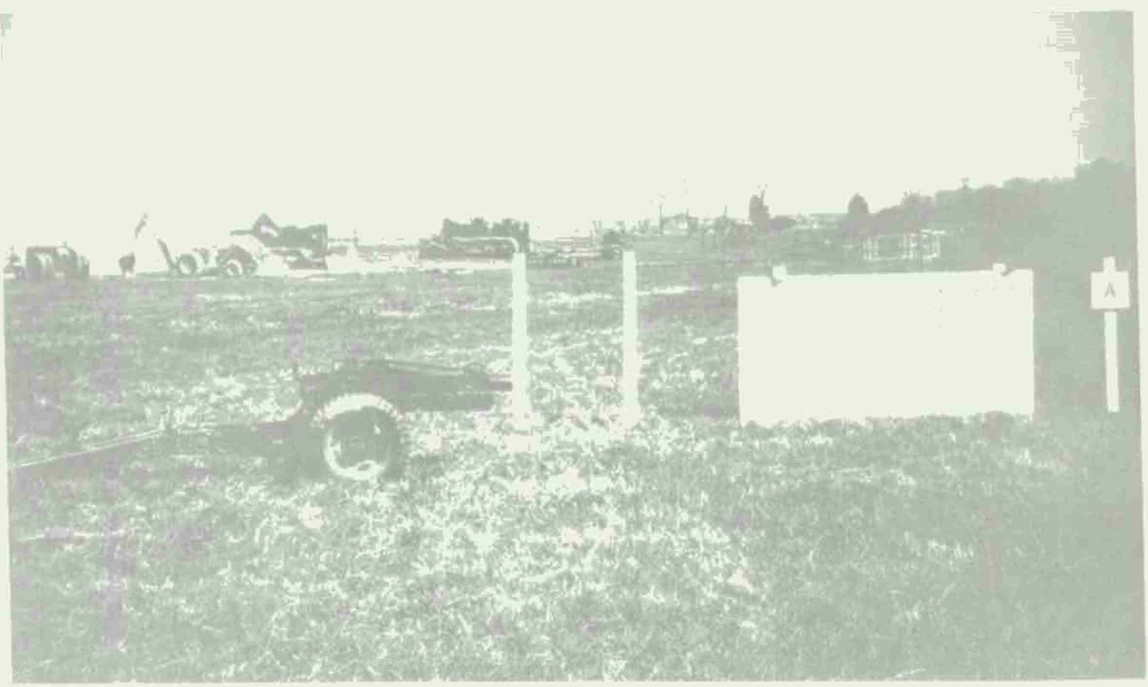
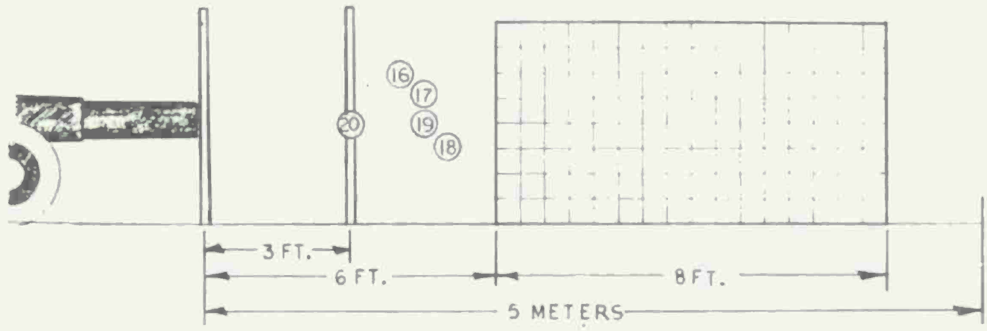


Figure 8. Beehive field-test arrangement.



ROUND	FUNCTION DIST. (FT.)	DIST. LESS 2MS DELAY (FT.)
16	4.0 (1.2 METERS)	1.5 (0.4 METERS)
17	4.5 (1.3 ")	2.0 (0.6 ")
18	5.0 (1.5 ")	2.5 (0.7 ")
19	4.5 (1.3 ")	2.0 (0.6 ")
20	3.0 (0.9 ")	0.5 (0.1 ")

FLASH CHARGE FUNCTION DISTANCES
ADVANCED BEEHIVE FUZE TEST 12 JAN 73

Figure 9. Beehive field-test results.

3.2 Tests Results

Five Advanced Beehive rounds were preset for muzzle action and fired at charge 4. All the rounds (tabulated on fig. 9) functioned within the required 16.4 ft from the gun muzzle. Figure 10 (p. 16) shows the sequence of muzzle action taken for one of the rounds.

4. CONCLUSIONS

A reed-type fluidic generator was developed as a power source for the Advanced Beehive Fuze. Air-gun tests conducted have shown this generator to be structurally adequate for the high-g environment (25 kg) encountered by the Beehive fuze. Laboratory tests have shown that the generator can meet the muzzle action requirements of the Beehive fuze. These tests have shown that the generator is capable of arming the fuze within the required 16.4 ft from the gun at simulated muzzle velocities from 1400 to 3000 ft/s.

Field tests of this generator design using flash charges have demonstrated the capability of the generator and the fuze electronics to function in the muzzle action mode. All five rounds functioned within the required 16.4 ft from the muzzle.

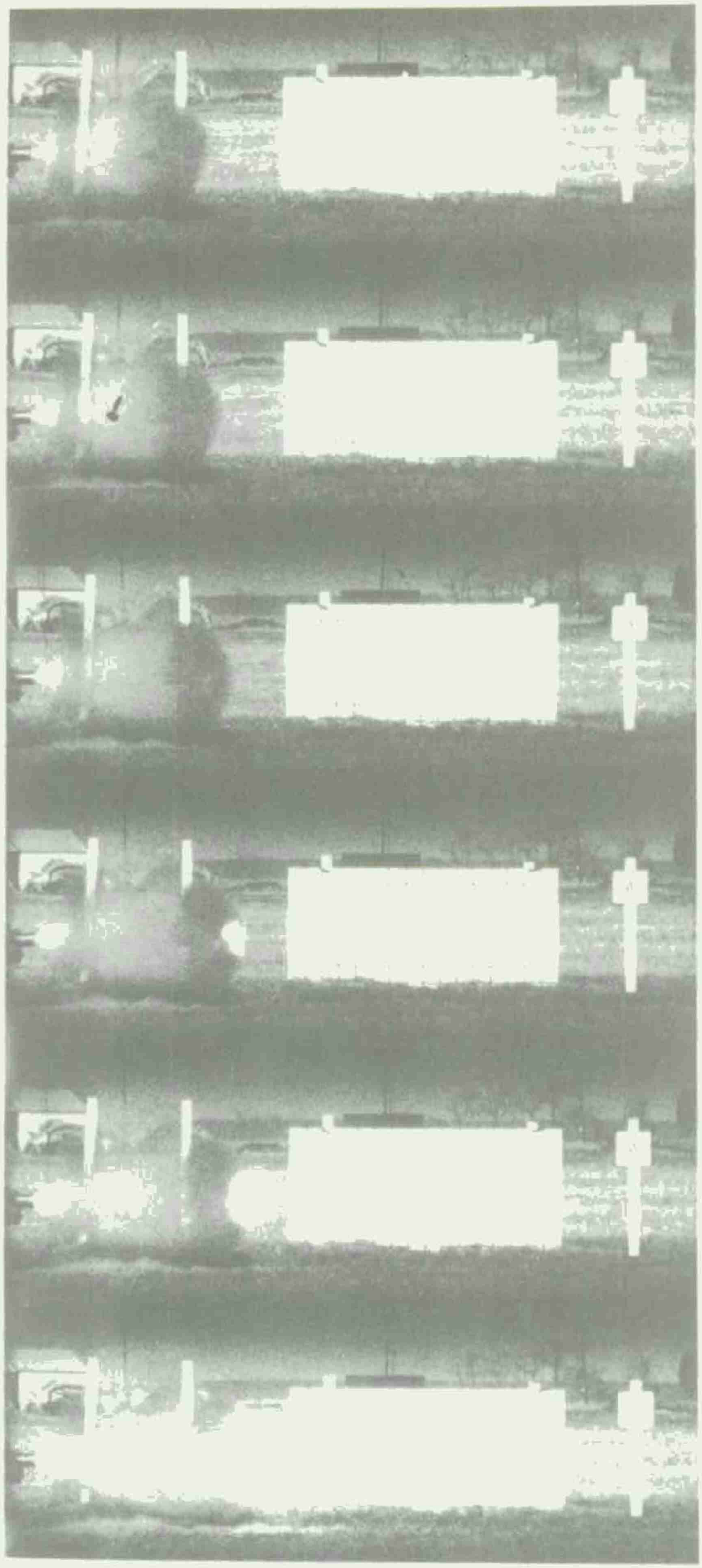


Figure 10. High-speed film coverage of one Beehive round taken during field test.

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